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DEVELOPMENT OF A ST. LAWRENCE ESTUARY MARINE PROTECTED AREA ECOLOGICAL MONITORING PLAN

Figure 1. Proposed location of the future St. Lawrence Estuary Marine Protected Area (MPA).

Context:

In support of the Health of the Oceans Initiative (component 21), Science sector is required to deliver indicators, protocols and strategies for monitoring the individual conservation objectives for established Marine Protected Areas (MPAs). Monitoring of biological and ecological indicators (and their respective threats) is applicable to: 1) incorporation into broader MPA monitoring "plans" or "programs" (addressed by the DFO Oceans Sector); 2) tracking status, condition and trends to determine if MPAs are effective in achieving their conservation objectives; 3) aiding managers in the review of MPA management plans to achieve conservation objectives; and 4) reporting to Parliament and Canadians (ultimately, via the management sector). Therefore, the selection of indicators and protocols for collection and analysis of data must be scientifically defensible.

In 1998, the St. Lawrence River was identified as a site of interest for creating a future MPA for the Quebec region. A scientific workshop held in 2000 confirmed the relevance of establishing this MPA to protect marine mammals, their habitats and food resources. This scientific advisory report proposes and assesses a series of threat indicators and their potential effects on marine mammals and the ecosystem to determine whether the related conservation objectives have been achieved. Monitoring programs (existing or proposed) are associated with them and are assessed in terms of reliability and ease.

SUMMARY

- Two types of indicators are presented: performance indicators directly related to the conservation objectives and ecosystem health indicators. The former relate to threats and their potential effects on marine mammals and their habitat and prey. MPA managers can use these indicators to determine whether conservation objectives have been achieved. Some of these indicators will be used to test the effectiveness of regulations, others the effectiveness of indirect measures, such as public awareness or the influence on decision-makers who are responsible for managing some of the threats. Ecosystem health indicators support the performance indicators by enabling us to detect changes or abnormalities in the environment that could affect the ecological components targeted by the conservation objectives.

- These indicators were assessed based on their relevance, determined by establishing the extent to which the indicator was appropriate for assessing the threat or the potential target effect. In all, 72 indicators were assessed of which 54 were highly relevant. Monitoring associated with the indicators was assessed for its reliability and ease of implementation. In general, the ease of conducting a survey decreases when we try to increase its reliability, given that reliability is often dependent on sampling effort.

- Highly relevant indicators are proposed for each threat and its potential effects on marine mammals, except for the disruption of important activities of cetaceans. Highly relevant indicators of the status of the physical-chemical and biological ecosystem are also proposed.

- Existing programs monitor a number of indicators with acceptable reliability and ease. Some of these must be expanded to cover the MPA. At least a quarter of the indicators require that new monitoring be set up. This includes monitoring noise in the water, contaminants in sediment and water, as well as in beluga whale and harbour seal prey that are not currently being monitored. Prey availability is a potential effect which is receiving little coverage under existing monitoring programs, especially with respect to prey such as krill, pelagic fish, coastal species of the lower estuary and demersal fish in the upper estuary. Also, implementing monitoring of the seabed and ocean circulation would enable us to assess changes in the habitats of various target species and changes in the environment in which they live.

- It goes without saying that the proposed indicators cannot all be monitored. However, the sound, simple criteria used to assess them will help managers to make informed choices based on the human and financial resources available when monitoring is implemented. In a context of reduced financial resources, it is suggested that the time between monitoring sampling periods be extended rather than decreasing the number or quality of surveys.

- The various government agencies (e.g. DFO, the Ministère des Ressources naturelles et de la Faune du Québec (MRNF) and Parks Canada) involved must join forces and work together to increase the efficiency of all monitoring related to the protection of marine mammals and their habitat and prey.

BACKGROUND

Description of the MPA

The MPA, with an approximate area of 6,000 km^2, will cover an area of the St. Lawrence estuary that will be peripheral and complementary to the Saguenay-St. Lawrence Marine Park (SSLMP). The St. Lawrence estuary is the main habitat of the beluga whales and harbour seals that live there year round. It also contains high concentrations of forage species such as euphausids (krill) and capelin, making it a feeding ground of critical importance to many marine mammals. Every year, many cetaceans, including large whales, migrate there to feed and build energy reserves in preparation for the breeding season. The great diversity and high density of marine mammal species found there, the proximity of observation sites and the relative tranquility of the sea also make the St. Lawrence estuary one of the most favourable locations in the world for observing marine mammals. Some 15 species of marine mammals are regularly or occasionally found in the estuary, mostly on a seasonal basis. Nearly half of the species are designated at risk by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC).

The topography and hydrodynamics of the St. Lawrence estuary are very complex. The St. Lawrence and Saguenay rivers discharge large amounts of freshwater into it. This is also where the Laurentian Channel, which carries a current of cold water from the Atlantic, ends. The various origins and characteristics of the water in the estuary create pronounced gradients of salinity and temperature, as well as distinct layers of water with thermocline interfaces. The exceedingly varied topography creates mixing zones, upwellings, gyres and retention phenomena. Finally, the cold winter weather produces very extensive seasonal ice cover.

Conservation Objectives

Under Canada's *Oceans Act*, the St. Lawrence Estuary MPA has been proposed to ensure the long-term conservation and protection of marine mammals and their habitats and food resources. This includes species that live there year round, such as beluga whales and harbour seals, as well as migratory species such as blue whales and fin whales. The other seal species, some of which are hunted, are not covered by this MPA. The conservation objectives set for the proposed MPA have been defined as follows:

1. Protect marine mammals
    - Objective 1A: Protect the resident species (beluga whales and harbour seals)
    - Objective 1B: Protect species at risk
    - Objective 1C: Protect other cetaceans
2. Protect marine mammal habitat
    - Objective 2A: Protect harbour seal habitat and its main functions
    - Objective 2B: Protect important habitats of species at risk, including critical habitat, and the functions of these habitats
    - Objective 2C: Protect the habitat of other cetaceans
3. Protect marine mammal prey
    - Objective 3A: Protect the main prey of species at risk
    - Objective 3B: Protect the habitat of the main prey

Human Activities and Threats

The St. Lawrence estuary receives the drainage waters of a vast, highly urbanized and industrialized watershed where intensive agricultural operations occupy a large part of the land. There are significant levels of maritime traffic, including merchant ships and tankers sailing through the seaway, ferries and fishing boats, in the Gulf of St. Lawrence. The area has also experienced a dramatic rise in whale watching cruises and boating. Marine mammals in this area face many threats including contamination of the marine food web by toxic substances, environmental noise, the risk of collision, disturbances related to navigation, entanglement in fishing gear, poaching, culling and physical alteration of their habitats and those of their prey.

Potential Impacts or Effects

Threats from human activities are only significant if they cause negative impacts on the ecological components of interest. It is therefore important to understand and monitor these impacts or effects. The main impacts or potentially significant effects, in that they could hinder the achievement of conservation objectives, both on prey and marine mammals are as follows (*there are many possible causes of these effects and the main causes are suggested in parentheses*):

- increased mortality (*collision, toxic algal blooms (biotoxins), entanglement in fishing gear, hunting and poaching, isolation and abandonment of harbour seal pups*);
- Increase in diseases that can have an impact on fertility and mortality (*toxic, chemical and biological contamination, epizooty, stress, injuries due to collision, fishing gear and hunting weapons*);
- Disruption of important activities, such as feeding, rest, communication, reproduction and respiration (*anthropogenic disturbance, noise and acoustic degradation*);
- Loss or disruption of habitat that can be used by marine mammals or their prey (*chemical or physical alteration of habitat, fishing gear and anthropogenic climate change*);
- Decrease in prey (*directed fishing of prey, toxic, chemical and biological contamination)*.

Overall, these negative effects on the marine mammals targeted by the MPA will result in:

- A decline in beluga whale and harbour seal populations (demographic impact) or the beluga whale's failure to recover; and
- A decrease or a recurring suboptimal presence of cetaceans in the St. Lawrence estuary.

ANALYSIS

Proposals for monitoring the MPA

Monitoring Indicators

The ecological monitoring plan for an MPA is primarily a tool for assessing the achievement of MPA conservation objectives. The monitoring plan must address the ecological components targeted by the MPA objectives, threats to these components and the potential effects of these threats. Indicators for every threat and each of their potential effects on the ecological

components of the MPA are therefore required. These indicators will be selected based on their ability to assess the achievement of conservation objectives and the effectiveness of the management measures applied within the MPA. Ideally, these indicators must provide a clear, direct response to the positive or negative results produced after a management measure has been introduced. However, in many cases, the link between the indicator's response and the effectiveness of the management measure is difficult to establish. Many threats to the MPA come from outside its boundaries and the ranges of a number of marine mammals and their prey extend far beyond the MPA. Also, the role of certain indicators will be to sound an alarm that will create awareness among the general public and policy makers who are responsible for managing certain threats.

In addition to threat indicators and indicators of the potential effects that the threats may have on the target ecological components, the MPA monitoring plan must include a set of indicators for the status of the physical, chemical and biological ecosystem. These indicators will provide information on the context in which the St. Lawrence estuary ecosystem is changing and detect changes or abnormalities in the environment that could affect the ecological components targeted by the conservation objectives. For example, large-scale changes in oceanographic and hydrological conditions could affect the ecological components of the MPA.

Assessment of the Proposed Indicators

Since its designation as a site of interest in 1998, several initiatives (work tables, workshops and research) involving various scientists have been undertaken to develop an ecological monitoring plan for the MPA to track every conservation objective (DFO 2000, DFO 2003, Mosnier *et al.* unpublished data and Ouellet *et al.* unpublished data).

A preliminary monitoring plan was developed on the basis of these consultations and research. On May 3, 4 and 5, 2011, a peer review involving nearly 40 scientists was conducted to assess the indicators and monitoring that comprised the preliminary monitoring plan. The progress and detailed results of the assessment are presented in the research paper related to this science advisory report (Provencher *et al.* 2012). The indicators that were assessed were divided into three sections: threat indicators, indicators of the potential effects of these threats and ecosystem health indicators. Each indicator was associated with existing monitoring or proposed new monitoring. Participants were asked to review these indicators and monitoring by confirming them, modifying them or proposing new ones. They were also to assess each of the indicators and their related monitoring, based on three criteria. The three criteria were selected to ensure that managers have easy access to the results and find them understandable and usable. This should help managers make informed decisions based on the scientific knowledge and financial resources available when the monitoring is implemented. These criteria are defined as follows:

Relevance: assesses the extent to which the indicator is relevant to the assessment of the threat or target effect (direct or indirect link with the threat or effect).

(1) Very relevant
(2) Less relevant
(3) Not relevant

The other two criteria assess the reliability and user friendliness of the tools (protocols, equipment and sampling) used or proposed for monitoring this indicator.

Reliability: assesses the extent to which we are certain of the results obtained while monitoring this indicator (accuracy, sensitivity, clear theoretical basis, evidence and research need).

(1) Highly reliable, compelling, excellent relationship
(2) Probable, useful although flawed information
(3) Doubtful, uncertain, highly variable

Ease: assesses the extent to which it is easy to measure this indicator. Is the sampling involved simple and inexpensive to perform? This contrasts with complex monitoring that requires sophisticated or uncommon expertise and significant financial, human and material resources.

(1) Easy (simple measurements and analyses, low costs, etc.)
(2) Intermediate
(3) Difficult (complex logistics, equipment or analysis, expertise is not readily available, significant resources required, etc.)

Tables 1, 2 and 3 show the results for each indicator and the related monitoring that was assessed based on these three criteria, but not the rationales and reasoning that led to these results. However, they are available in the research paper related to the science advisory report (Provencher *et al.* 2012). In all, 72 indicators were assessed, 54 of which were highly relevant, 15 less relevant and 3 not relevant. Highly relevant indicators were proposed for each threat and potential impact on marine mammals, except for the disruption of important activities of cetaceans. More than 10 relevant indicators were proposed for monitoring the status of the ecosystem, assessed in accordance with its physical, chemical and biological aspects. Few (existing or proposed) monitoring methods were highly reliable and very easy. However, most received intermediate ratings.

Legend for Tables 1, 2 and 3:

Columns Rel, Rty, and EZ of the three tables refer to the three criteria used to assess indicators and monitoring: relevance, reliability and ease. Each criterion was scored on a scale of 1 to 3. The "M" column in the tables identifies the monitoring that was assessed; the monitoring numbers are preceded by the letter E (for existing monitoring) or the letter P (for proposed potential monitoring). Monitoring under development is marked "Dev". Monitoring related to data points are marked "n/a." The list and description of the monitoring are presented in the research paper related to the scientific advisory report (Provencher *et al.* 2012). Their reliability and ease are discussed in the next section on the monitoring review.

Table 1. Results of the assessment of threat indicators and related monitoring (M), based on the criteria of relevance (Rel), reliability (Rty) and ease (EZ).

	Indicators	Rel	Rty	EZ	M
Threat: Toxic chemical pollution (resident species and prey)					
1	Contamination levels of harbour seal and beluga whale prey	1	1	2	P9
2	Contaminant levels in beluga whale and harbour seal tissue	1			
	Demographic monitoring of harbour seals		1	2	E1
	Beluga carcass monitoring program		2	2	E9
	Biopsy of live beluga whales		2	2	P8
3	Contamination rate of a resident sentinel species	2			
			1	2	Dev
4	Measurements of toxic chemical contaminants (old and new)	2			
	In sediment		1	2	P17
	In water		1	3	P17
Threat: Noise (resident and migratory species)					
5	Noise measurement in water (intensity and frequency for beluga whales and rorquals) at highly frequented sites	1			
	Passive acoustics, fix sites, continued listening		1	3	P1
	Passive acoustics, extended points, discrete listening		1	2	P2
6	Intensity and distribution of marine shipping traffic (vessel type, tonnage, speed, etc.).	2			
	INNAV database		1	1	E31
7	Intensity and distribution of recreational and tourist marine traffic (vessel type, speed, etc.).	2			
	Marine observation activities (MOA)		3	2	E7
Threat: Collisions (resident and migratory species)					
8	Number of collisions reported	1			
	Réseau québécois d'urgences pour les mammifères marins (RQUMM)		2	3	E8
	INNAV database		2	3	E31
	SSLMP collision reports		2	3	E32
9	Number of animals with marks or recent injuries related to collisions	1			
	Cetacean photo-identification		3	3	E4
	Réseau québécois d'urgences pour les mammifères marins (RQUMM)		3	3	E8
	Beluga carcass monitoring program		3	3	E9
6	Intensity and distribution of marine shipping traffic (vessel type, tonnage, speed, etc.)	2			
	INNAV database		1	1	E31
7	Intensity and distribution of recreational and tourist marine traffic (vessel type, speed, etc.)	2			
	Réseau d'observation de mammifères marins (ROMM)		3	2	E5
	Marine observation activities (MOA)		3	2	E7

Threat: Disturbance (resident and migratory species)

10	Concentration of boats within compliance radius around cetaceans Marine observation activities (MOA)	1	 2	 2	 E7
11	Frequency of boats and hikers near harbour seal haul-out sites during the high season Réseau d'observation de mammifères marins (ROMM)	1	 2	 1	 E5
12	Number of permits for scientific research and type of projects	1	1	1	n/a
7	Intensity and distribution of recreational and tourist marine traffic (vessel type, speed, etc.) Réseau d'observation de mammifères marins (ROMM) Marine observation activities (MOA)	2	 3 3	 2 2	 E5 E7
13	Number of trips to observe marine mammal and target species Marine observation activities (MOA)	2	 2	 1	 E7
6	Intensity and distribution of marine shipping traffic (vessel type, tonnage, speed, etc.). INNAV database	3	 1	 1	 E31
14	Number of marine mammal observation permits. Marine observation activities (MOA)	3	 1	 1	 E7

Threat: Habitat alteration (resident and migratory species)

15	Number and type of development projects	1	2	1	n/a
16	Fishing intensity, distribution, gear Fisheries statistics	1	 1	 1	 E14
17	Frequency, location, area and volume of dredging channels and sediment deposits	1	 1	 1	 n/a
18	Changes in freshwater flows related to local or neighbouring hydroelectric facilities	2	 1	 1	 n/a

Threat: Poaching and culling

19	Number of poaching incidents Réseau québécois d'urgences pour les mammifères marins (RQUMM)	1	 3	 2	 E8

Threat: Entanglement in fishing gear

20	Number of accidental catches related to fishing (circumstances, dates and places), types of fishing gear and species involved. Réseau québécois d'urgences pour les mammifères marins (RQUMM)	1	 3	 2	E8
21	Number, duration and distribution of rock crab, whelk, sturgeon and eel fisheries (shoreline, coastal and offshore). Established fisheries statistics Emerging fisheries statistics	2	 1 2	 1 1	E14

Table 2. Results of the assessment of indicators of the potential effects on marine mammals, their habitats and prey and related monitoring (M), based on the criteria of relevance (Rel), reliability (Rty) and ease (EZ).

RESIDENT SPECIES: BELUGA WHALE AND HARBOUR SEAL

	Indicators	*Rel*	*Rty*	*EZ*	*M*
Impact: Disease					
22	Frequency of marine mammal diseases	1			
	Beluga carcass monitoring program		2	3	E9
	Biopsy of live beluga whales		3	2	P8
23	Condition index (various tissues) and reproductive status (ovaries) of beluga whale carcasses	3			
	Beluga carcass monitoring program		2	3	E9
Impact: Mortality					
24	Number of carcasses and their spatial and temporal distribution	1			
	Réseau québécois d'urgences pour les mammifères marins (RQUMM)		2	2	E8
25	Directory of causes of death	1			
	Beluga carcass monitoring program		2	3	E9
	Photos taken at stranding site		3	1	-
26	Demography of dead individuals	1			
	Beluga carcass monitoring program		2	2	E9
Impact: Disruption of important activities					
27	Reported number and location of isolated juvenile seals	1			
	Réseau québécois d'urgences pour les mammifères marins (RQUMM)		2	2	E8
28	Sound masking index of beluga whale communications and vocalizations	2			
	Passive acoustics, fix sites, continued listening		2	3	P1
	Passive acoustics, extended points, discrete listening		2	2	P2
29	Diving behaviour modification	2			
	Diving behaviour changes monitored by telemetry		2	3	P6
Impact: Usable habitat loss or disruption					
30	Intensity of beluga whale use of major areas of aggregation for food, care for young and reproduction	1			
	Aerial beluga whale inventory		2	2	E2
	Monitoring of some intensive use areas		2	2	P4
31	Intensity of harbour seal use of haul-out sites depending on the season	1			
	Demographic monitoring of harbour seals		2	2	E1
	Aerial monitoring		2	2	P5

32	Percentage of grey seals at harbour seal haul-out sites	2			
	Demographic monitoring of harbour seals		2	2	E1
	Aerial monitoring		2	2	P5

Impact: Variation in the harbour seal population

33	Evolution of abundance at the various haul-out sites over time	1			
	Demographic monitoring of harbour seals		2	2	E1
	Aerial monitoring		2	2	P5
34	Number of births at control sites (Bic and Métis)	1			
	Demographic monitoring of harbour seals		2	1	E1
35	Survival rate based on growth of pups before weaning	2			
	Demographic monitoring of harbour seals		3	3	E1

Impact: Variation in the beluga whale population

36	Evolution of abundance of beluga whales over time	1			
	Aerial beluga whale inventory		2	2	E2
37	Evolution of the distribution (expansion or contraction) of beluga whales over time	1			
	Aerial beluga whale inventory		2	2	E2
38	Percentage of juveniles in the population	1			
	Aerial beluga whale inventory (photographic surveys)		2	2	E2
39	Percentage of pregnant females (progesterone in blubber)	2			
	Biopsies of live beluga whales		2	3	P8

MIGRATORY SPECIES: CETACEANS

Impact: Mortality

40	Number of carcasses and their spatial and temporal distribution	1			
	Réseau québécois d'urgences pour les mammifères marins (RQUMM)		2	2	E8
41	Directory of causes of death	1			
	Analysis of digital photographs taken on site		3	1	E8
	Necropsy of carcasses		2	3	E8

Impact: Disruption of important activities

42	Sound masking indices of rorqual communications and vocalizations	2			
	Passive acoustics, fix sites, continued listening		2	3	P1
	Passive acoustics, extended points, discrete listening		2	2	P2
43	Changes in rorqual diving behaviour.	2			
	Changes in diving behaviour monitored by telemetry		2	3	P6

Impact: Change in the use of MPAs by rorquals

44	Relative abundance of rorquals from year to year	1			
	Réseau d'observation de mammifères marins (ROMM)		3	1	E5
	Visual rorqual surveys		1	3	E6
	Marine observation activities (MOA)		2	2	E7
45	Average annual residence time per individual (blue whales and fin whales)	1			
	Rorqual monitoring by satellite telemetry		3	3	P3
46	Area use indices	1			
	Passive acoustics, fix sites, continued listening		2	3	P1
	Visual rorqual censuses (Density)		1	3	E6
	Marine observation activities (MOA) (Density)		2	2	E7
47	Number of individual blue whales frequenting the St. Lawrence estuary	1			
	Cetacean photo-identification		2	3	E4
	Visual rorqual surveys		2	3	E6

MARINE MAMMAL PREY

Impact: Availability and quality of krill

48	3D spatial distribution by species in the St. Lawrence estuary	1			
	Weekly monitoring of prey in SSLMP		2	2	E23
	Annual acoustic survey of krill		2	2	P12
49	Biomass index (by krill species)	1			
	Assessment of zooplankton biomass		3	3	E12
	Weekly monitoring of prey in SSLMP		2	2	E23
	Annual acoustic survey of krill		2	2	P12
	Rimouski monitoring station (AZMP)		2	1	E11
50	Density index (by krill species)	1			
	Weekly monitoring of prey in SSLMP		2	2	E23
	Annual acoustic survey of krill		2	2	P12
51	Krill condition index	1	2	2	Dev
52	Krill transport potential	2			
	Monitoring by ADCP mooring (backscatter)		2	3	P14
	Daytime krill transport index		2	1	P13
	Valve open / closed index		2	1	Dev

Impact: Availability and quality of fish

53	Abundance of pelagic fish (herring, capelin and sand lance), diadromous fish (salmon, eel, tomcod, smelt and sturgeon) and demersal fish (white hake, cod, redfish, American plaice, shorthorn sculpin and smooth flounder)	1			
	<u>Pelagic fish</u>				
	Annual acoustic monitoring of pelagic fish		2	2	P10
	Weekly monitoring of prey in SSLMP		2	2	E23
	Ichthyoplankton surveys		2	2	P11
	Monitoring of juvenile rainbow smelt		2	2	E19

	Diadromous fish				
	Fisheries statistics		2	1	E14
	Réseau d'inventaire des poissons de l'estuaire (RIPE)		2	1	E17
	Silver eel abundance monitoring		2	1	E20
	Sturgeon landings monitoring		2	2	E21
	Monitoring of salmon in rivers		1	1	E22
	Demersal fish				
	Multi-species surveys in the lower estuary		2	2	E13
	Annual acoustic monitoring of pelagic fish		3	2	P10
54	Distribution of pelagic, diadromous and demersal fish	1			
	Pelagic fish				
	Annual acoustic monitoring of pelagic fish		2	2	P10
	Weekly monitoring of prey in SSLMP		2	2	E23
	Diadromous fish				
	Fisheries statistics		2	1	E14
	Demersal fish				
	Multi-species surveys in the lower estuary		2	2	E13
	Annual acoustic monitoring of pelagic fish		3	2	P10
55	Biological effects of contaminants on the quality of prey	1			
	Visual monitoring		2	1	Dev
	Biomarkers		2	2	Dev
56	Condition indices of the main prey	1	-	-	Dev
57	Composition index of the beluga whale and harbour seal diet	2			
	Chemical tracers (stable isotopes, fatty acids and contaminants)		3	2	P7
	Beluga carcass monitoring program (stomach contents)		3	3	E9
58	Fish community (coastal and the entire estuary) diversity indices for beluga whale prey	2			
	Multi-species surveys in the lower estuary		2	2	E13
	Réseau d'inventaire des poissons de l'estuaire (RIPE)		2	1	E17

Impact: Disruption and loss of habitat usable by prey

59	Fidelity to known spawning site grounds every year	1			
	Capelin Observers Network		3	1	E15
	Seabed monitoring via imaging		2	2	P18
60	Changes in the characteristics of prey spawning sites	1			
	Capelin Observers Network		3	1	E15
	Seabed monitoring via imaging		2	2	P18
	Monitoring of rainbow smelt spawning sites in the south estuary		2	2	E18
61	Change in coverage area of marshes, eelgrass beds and kelp beds	2			
	Satellite photo monitoring of marshes and eelgrass beds		2	2	P20
	Seabed monitoring via imaging		2	2	P18

Table 3. Results of the assessment of ecosystem status indicators and related monitoring (M), based on the criteria of relevance (Rel), reliability (Rty) and ease (EZ).

	Indicators	Rel	Rty	EZ	M
Physical-chemical aspect of the ecosystem					
62	Changing characteristics of the hydrological regime related to freshwater entering the estuary (flow and precipitation)	1			
	Monitoring of freshwater flow at the Quebec City station		1	1	E34
63	Changing characteristics of the hydrological regime linked to the open vs. closed ratio of the zooplankton valve	1			
	Monitoring by ADCP moorings		2	3	P14
	Monitoring via 3D modelling of ocean circulation		2	2	P16
	Monitoring of wind (strength and direction) as a proxy		3	1	P15
64	Spatial-temporal changes in oceanographic conditions (salinity, temperature, oxygen, pH, turbidity, flow, stratification and nutrients)	1			
	Weekly monitoring of prey in SSLMP		1	2	E23
	Thermograph network		1	1	E24
	Helicopter monitoring of winter waters		1	2	E25
	Remote sensing of surface temperatures		1	2	E26
	Atlantic Zone Monitoring Program		1	2	E11
	On-line Scientific Buoys network		1	2	E33
65	Ice cover (area, thickness and period)	1	1	1	E35
4	Measurements of toxic chemical contaminants (old and new) in sediment and water	1			
	In sediment		1	2	P17
	In water		1	3	P17
3	Contamination rate of a resident sentinel species	1	1	2	Dev
66	Changing characteristics of the wind regime (upwelling and stratification index)	2	1	1	Dev
Biological aspect of the ecosystem					
58	Diversity of fish communities	1			
	Multi-species surveys in the lower estuary		2	3	E13
	Réseau d'inventaire des poissons de l'estuaire (RIPE)		2	1	E17
67	Variations in biomass, composition and distribution of phytoplankton communities	1			
	Rimouski monitoring station (AZMP)		2	2	E11
	Transect monitoring (AZMP)		3	2	E11
	Remote sensing of primary productivity		3	2	E27
	Toxic Algae Monitoring Program		2	2	E28
68	Spatial-temporal evolution of toxic algae	1			
	Toxic Algae Monitoring Program		1	2	E28
			3	1	E29

	Canadian Shellfish Sanitation Program				
69	Variations in the composition and distribution of benthic communities	1			
	Seabed monitoring via imaging		2	2	P18
	At-sea sampling of the endobenthos		2	3	P19
70	Variations in biomass, composition and distribution of zooplankton communities	1			
	Rimouski monitoring station (AZMP)		2	2	E11
	Transect monitoring (AZMP)		3	2	E11
	Weekly monitoring of prey in SSLMP		2	2	E23
	Annual acoustic survey of krill		2	2	P12
71	Species diversity of marine mammals	1			
	Aerial beluga whale inventories		3	2	E2
	Visual cetacean censuses		2	3	E6
	Marine observation activities (MOA):		2	2	E7
	Réseau québécois d'urgences pour les mammifères marins (RQUMM)		3	2	E8
	Nouvelles du large GREMM		3	1	E10
	Weekly monitoring of prey in SSLMP		2	2	E23
72	Biological effects of environmental stressors on sentinel species	1			
	Visual monitoring:		2	1	Dev
	Biomarker monitoring		2	2	Dev
64	Spatial-temporal changes in oceanographic conditions (salinity, temperature, oxygen, pH, turbidity, flow, stratification and nutrients)	1			
	Weekly monitoring of prey in SSLMP		1	2	E23
	Thermograph network		1	1	E24
	Helicopter monitoring of winter waters		1	2	E25
	Remote sensing of surface temperatures		1	2	E26
	Atlantic Zone Monitoring Program		1	2	E11
	On-line Scientific Buoys network		1	2	E33
65	Ice cover (area, thickness and period)	1	1	1	E35

Monitoring Review

Existing programs monitor a number of indicators related to threats and their potential effects on marine mammals and their prey, with acceptable reliability and ease. However, some of them must be expanded to cover the entire MPA. In addition, new monitoring has to be established for at least a quarter of the indicators. For example, (old and new) contaminants in sediment and water as well as in the prey of beluga whales and harbour seals are not being monitored. The threat of noise in the water is not being monitored either. Prey availability is a potential effect receiving little coverage under existing monitoring programs, especially with respect to prey such as krill, pelagic fish, coastal species of the lower estuary and demersal fish in the upper estuary. Also, implementing monitoring of the seabed and ocean circulation would enable us to assess changes in the habitats of various target species and changes in the environment in which they live. In general, the ease of conducting a survey decreases when its reliability increases, given that reliability often depends on sampling effort.

Marine mammals

Aerial inventories of beluga whales (E2) and harbour seals (P5)
Indicators: 30, 31, 32, 33, 36, 37, 38,

Since 1988, the Department of Fisheries and Oceans (DFO) has performed 36 systematic air surveys (28 visual and 8 photographic surveys) between Rimouski and Petite-Rivière-Saint-François. These surveys have monitored population trends, animal distributions and intensity of beluga whale use of major aggregation areas, and assessed the number of juveniles. Despite relatively high variability from year to year, the monitoring has been reliable enough to establish long-term trends. This reliability was dependent on the variability of the beluga whale range (one inventory per year) and the statistical analysis of the results. This variability limited its usefulness for quickly detecting problems. These surveys, conducted from July to September, only covered the summer season. However, this inventory methodology has been fine-tuned and is relatively inexpensive.

Harbour seals in the estuary were monitored via aerial surveys of haul-out sites conducted by helicopter from 1994 to 2001. These periodic aerial inventories are relatively inexpensive in a small area like the estuary and should be pursued. The quality and interpretation of the results are good provided there is sufficient observation effort. They provide an indicator of change in the abundance and distribution of the species. They detect expansion toward new sites, which may indicate improved conditions. These inventories can also be used to monitor the abundance of grey seals, a species in competition with harbour seals in other areas, and thus determine their relative abundance over time at the various haul-out sites.

Monitoring of certain sites used by beluga whales (P4) and harbour seals (E1)
Indicators: 2, 30, 31, 32, 33, 34, 35

One of the beluga whale's intensive use areas was monitored at Pointe-Noire in the SSLMP. Similarly, one or two beluga whale aggregation sites within the boundaries of the MPA should be targeted (P4). Intensive monitoring could be conducted at the selected sites during periods of maximum beluga whale use to better understand how beluga whales use these areas and ensure the long-term viability of this habitat. However, there are fewer suitable shore-based observation sites in the MPA. The Kamouraska area appears to be an interesting site.

DFO and recently Laval University (E1) have conducted research and monitoring at two harbour seal haul-out sites (Bic and Métis). This monitoring assesses the annual number of births and changes in the relative abundance of harbour seals over time at these sites. The average

growth rate during the period before weaning and contaminant levels in harbour seal tissue are also monitored. In addition, this monitoring determines the percentage of grey seals that occupy these sites. Grey seals are in competition with harbour seals. Funding for this program has been secured only until 2013, but the program is nevertheless likely to be continued.

Visual rorqual censuses (E6)
Indicators: 44, 46, 47, 71

As part of complementary projects, Parks Canada, GREMM and DFO conduct visual surveys of cetaceans along determined transects to characterize whale attendance and seasonal use of the estuary, which are used to produce spatial and temporal distributions of densities by species every year. A count is also performed from land in two of the three priority habitats targeted under the "agir sur le terrain pour les baleines en péril au parc marin" program [acting in the field for endangered whales in the marine park]. In collaboration with Parks Canada since 2006 and DFO since 2007, the Groupe de recherche et d'éducation sur les mammifères marins (GREMM) has conducted more systematic temporal monitoring of blue whales and other marine mammals in the estuary via weekly surveys along with photo-identification efforts in the case of blue whales. Data on the number and identity of blue whales frequenting the estuary (and the northwest part of the Gulf) have also been collected by the MICS (Mingan Island Cetacean Study) since 1987. The Réseau d'observation de mammifères marins (ROMM) also collects data on the number of blue whale sightings in this area. Annual visual censuses are more likely to be reliable, but their costs are very high in terms of personnel and vessel time.

Cetacean photo-identification (E4)
Indicators: 9, 47

Patterns of external marks documented by photography are used to identify individual whales and study their presence in the St. Lawrence estuary. Photo-identification is used to monitor whale movements, social organization and behaviour. Several research organizations keep catalogues of photo-IDs of whales in the St. Lawrence. The MICS catalogue contains more than 400 blue whales identified since 1979 in the northern Gulf and the St. Lawrence estuary. The Groupe de recherche et d'éducation sur les mammifères marins (GREMM), in collaboration with Parks Canada, has kept a catalogue of beluga whales, fin whales and other cetaceans in the estuary since 1986. The ORES (Ocean Research and Education Society) has also developed a minke whale catalogue. DFO regularly contributes to the MICS and GREMM catalogues. In the area off the Gaspé Peninsula, ROMM and the Centre d'étude et de protection de la baleine Noire du Saint-Laurent (CEPBaN) contribute to these collections.

Whale monitoring by telemetry (P3, P6)
Indicators: 29, 43, 45

Monitoring rorquals by satellite telemetry (satellite transmitters on individuals) (P3) would enable us to track the blue whale's use of the estuary and the Gulf of St. Lawrence during the summer and identify critical habitat for this species. However, making a sufficient number of observations to ensure the reliability of this type of monitoring may not be possible, partly because these data are very costly in terms of equipment, personnel and vessel time.

Monitoring wounded or dead (stranded) animals (E8, E9, E31, E32)
Indicators: 2, 8, 9, 19, 20, 22, 23, 24, 25, 26, 27, 40, 41, 57, 71

The Quebec Marine Mammal Emergency Response Network (RQUMM), which sends animals in distress to GREMM, in collaboration with 13 partners including DFO and Parks Canada, has various mandates, including promoting the acquisition of knowledge about animals that are dead, stranded or adrift in the waters of the St. Lawrence River in Quebec (E8). When the

carcasses of these animals are in good condition, the cause of death can be determined either on site when the cause is obvious (e.g. a bullet hole) or by transporting them to the Université de Montréal Faculty of Veterinary Medicine whose staff perform necropsies on species small enough to be moved. For beluga whales, this is done systematically through the beluga carcass monitoring program (see E9). Carcasses of other species are transported when financial resources are available. The sites are not always easy to access and experts not always available to travel to the site to confirm the deaths and the species involved. Necropsies performed on site are expensive, especially when blue whales are involved. Up to a certain extent, RQUMM provides information on indicators relating to threats such collisions, poaching and entanglements. However, the data's reliability is compromised by the bias in the rate and accuracy of reports and the representativeness of strandings.

The Fisheries and Oceans Canada (E9) carcass monitoring program has been in operation since 1982. Researchers at the Institut national d'écotoxicologie du Saint-Laurent sample carcasses stranded on the beach or transport them to the Université de Montréal Faculty of Veterinary Medicine where pathologists determine the causes of death and diseases. Carcass transportation, necropsies and disease analyses are costly and complex. Because of the advanced state of decomposition of some carcasses and other factors, the cause of death cannot be determined in a significant percentage of cases. However, this program has enabled us to identify previously unknown diseases, which seriously affect beluga whales (cancer, verminous pneumonia, collisions, certain infections, etc.). Under this program, tissue samples are also collected to determine age and gender and establish the temporal trend of the contamination of the beluga whale population by toxic, persistent organic compounds of anthropogenic origin (polychlorinated biphenyls (PCBs), dichlorodiphenyltrichloroethane (DDT), Mirex and polybrominated diphenyl ethers, (PBDEs)) for the purpose of studying exposure to certain contaminants. These stranded beluga whales are not necessarily representative of the population, and the low number of good quality tissue samples makes it difficult to detect annual trends for contaminants, pathogens or causes of death. Despite these biases, the carcass program has played an important role in identifying potential threats to the recovery of the population when it was assessed in 2007 (DFO 2007). However, there is uncertainty as to whether the program will continue in 2012.

In the SSLMP, recent collisions or injuries (E32) have also been monitored since 2003. All collisions with a marine mammal must be reported to the marine park. Also, the Université de Montréal has developed a spatial-temporal model of maritime traffic and marine mammal movements in the SSLMP + MPA area (E31). This model (Marine Mammal and Marine Traffic Simulator), which uses the Integrated Information System on Marine Navigation (INNAV) and those of MOAs and other data on the distribution of marine mammals, is used to assess the evolution of risk factors for fatal collisions based on navigation activity in the study area.

Biopsies on live belugas whales (P8)
Indicators: 2, 22, 39

GREMM has performed biopsies on belugas whales since 1994 to identify gender and family ties. A biopsy, performed using a crossbow armed with a special dart-tipped bolt, yields a small piece of skin and fat from the top layer of the fatty tissue. Information on accumulated pollutants could be collected using the same samples. Although little is known about the dynamics of persistent contaminants in the various layers of fat, this monitoring could be used to identify the levels and types of toxic chemical contaminants accumulated in live animals of this species. Also, the same sample could be used to determine the stage of maturity or the period of the reproductive cycle in females based on the progesterone level. However, testing protocols are not yet fully developed.

Marine mammal observation networks or programs (E5, E7, E8, E10)
Indicators: 7, 10, 11, 13, 14, 44, 46, 71

There are many observation networks or programs in the MPA and nearby (e.g. SSLMP). All these programs feed into monitoring the relative abundance and presence of whales and provide information on the evolution of marine observation activities, recreational and tourist maritime traffic and the presence of hikers near the haul-out sites.

Since 1998, the ROMM (E5) has been collecting data on whales and seals observed throughout their active season as part of a broad environmental observation project seeking to better define the distribution of these animals in the St. Lawrence. The cornerstone of the organization is a well established network of observer members, including excursionists, who cover different areas, conservation parks and ocean carriers.

GREMM and Parks Canada have been studying marine mammal observation activities (MOA) (E7) since 1994, with observers on excursion boats. This MOA monitoring program provides a partial view of the distribution of cetaceans: that of observation sites in the SSLMP. The study area covered by this project was expanded in 2005 to include the area of the future St. Lawrence Estuary MPA. Monitoring of this new area was suspended in 2010.

GREMM has developed a whale observer network with members located from Tadoussac to Percé and Anticosti (E10). The network notifies GREMM when marine mammals are present and/or specific events occur in each region. GREMM then compiles the information and sends it as news to observers and those who subscribe to the "*Les nouvelles du large*" site.

Some degree of inaccuracy is inherent in most of the data produced by these programs, depending on the level of effort, and they can be difficult to interpret. The observations of ROMM volunteers are data that are easy to obtain, but whose value as an indicator is not reliable. Observations (MOA) depend on the operators' activities at sea. However the data are collected systematically by trained observers. *Les Nouvelles du large* provides anecdotal but inexpensive data. These data are not reliable and cannot be used to determine trends.

Monitoring of ambient noise and rorqual and beluga whale vocalizations using passive acoustics (P1 and P2)
Indicators: 5, 28, 42, 46

Two methods involving passive acoustic technology are proposed for monitoring ambient noise and rorqual and beluga whale vocalizations at target sites. By monitoring vocalizations we obtain an indicator of the presence of rorquals and beluga whales, but its reliability must be validated.

One of the methods involves installing autonomous hydrophones at strategic sites (P1). The estuary, which is less than 25 km wide, is a suitable place to build a listening network. The recordings should be coupled with trips to sea to validate detections. The costs involved in this type of network are high due to the initial purchase and maintenance of hydrophones moored at several sites. However, over the long term, these costs will be offset by continuous automatic operation. The second method uses portable hydrophones successively placed at strategic sites (P2). Sites are visited every day to make a short recording for a period and at a predetermined frequency. The current data were acquired every day from mid-June to mid-September in six habitats highly frequented by beluga whales, including the Cap Bon Désir area, which is also frequented by the large whales. The method involving fixed hydrophones provides less spatial coverage than the second method. However, it allows these variables to be

monitored throughout the year and covers winter, a period for which there would otherwise be no data.

Prey

Krill monitoring (E11, E12, E23, P12, P13, P14)
Indicators: 48, 49, 50, 52, 70

Two krill surveys are currently underway. The zooplankton biomass assessment survey (E12) operates a grid of 44 stations and covers the western Gulf of St. Lawrence in the lower estuary (3 stations in the MPA). The reliability of the results of this type of monitoring depends on the variability of the spatial and temporal distribution of krill and the effort invested in the surveys. This survey is very expensive in terms of logistics and laboratory analyses. It had been in operation since 1994, did not take place in 2010 and remained uncertain for 2011. Another survey implemented in 2009 by Parks Canada involves weekly readings by hydroacoustic surveys of the abundance and distribution of pelagic prey in the SSLMP (Baie Sainte-Marguerite, the head of the Laurentian Channel and the mouth of the Saguenay) (E23).

New surveys are proposed for monitoring the density, distribution and biomass of krill and its transport potential. An annual acoustic survey (P12) covering the estuary and the northwest Gulf of St. Lawrence is a simple, direct method that enables us to monitor the fluctuations of krill production in the Gulf and its transport in the estuary. However, the most appropriate time and the extent of the area to be covered should be defined in order to complete the missions. A sampling of zooplankton must be performed for validation. Weekly surveys, like those performed in the SSLMP, would provide good temporal coverage, but would be expensive to extend to the MPA. We currently have three years of data (2008–2010) collected as part of the Ecosystem Research Initiative (ERI) in the Quebec region. Surveys are planned for the next three years.

Observations using ADCP (*Acoustic Doppler Current Profiler*) technology would enable us to continuously monitor zooplankton, including krill, via backscatter (P14). This monitoring provides very good (continuous) temporal coverage which extends throughout the year. However, spatial coverage is limited to fixed stations. Also, the devices must be placed at strategic locations for optimal sampling of the zooplankton corridor. We plan to use these data to develop an open / closed zooplankton valve index, which will be easy to use to determine krill transport potential once validated. As part of the ERI, these instruments (5 moorings and 6 devices) were deployed along the krill transport route in the northwest gulf and the St. Lawrence estuary in 2008–2009.

A daytime krill transport index (P13) is being developing under the ERI, which would be used to calculate its residence time in the estuary for a given period. However, this index must be validated, but requires data readily available from the CTD (Conductivity, Temperature, Depth) recorders installed in the estuary as part of several existing surveys.

As part of the Atlantic Zone Monitoring Program (AZMP) (E11), the Rimouski fixed monitoring station is sampled (20 to 25 trips per year) from April or early May until as late as possible in the fall to cover the entire seasonal cycle of copepod species dominant in this area. The average annual abundance of krill egg masses is measured and indicates the presence of krill. Interannual variations in krill recruitment success are a prime factor in explaining the variations of biomass in the lower estuary of the St. Lawrence. Monitoring has been conducted at this station since 1989.

Fish monitoring (E13, E14, E15, E17, E19, E20, E21, E22, E23, P9, P10, P20)
Indicators: 1, 16, 53, 54, 57, 58, 59, 60, 61, 69

Pelagic fish
There is virtually no monitoring being conducted on pelagic fish in the MPA. Since 2002, the MRNF has been monitoring juvenile rainbow smelt (*Osmerus mordax*) of the population in the southern St. Lawrence estuary in two main larval retention areas: Anse Sainte-Anne and the Rivière du Loup sandbank (E19). The purpose of this monitoring is to assess the abundance of smelt during the year to obtain an indication of annual recruitment. This monitoring does not cover smelt from the north shore of the estuary. The weekly hydroacoustic surveys conducted by Parks Canada (see above-mentioned krill surveys) cover pelagic prey, but only on the edge of the MPA (Baie Sainte-Marguerite, the head of the Laurentian Channel and the mouth of the Saguenay) (E23).

To address this shortcoming, monitoring via acoustic surveys throughout the MPA is proposed (P10). This technique is used to distinguish fish with swim bladders (e.g.: capelin and herring) from fish without swim bladders (e.g.: sand lance and mackerel). The method will have to be developed in order to distinguish between different species, for example, between capelin and herring, which both have a swim bladder. Validation must be performed via pelagic trawl sampling or a camera. Abundance, biomass and fish condition measurements can be taken on the species harvested. Weekly surveys, like those performed in the SSLMP, would provide good temporal coverage, but would be expensive to extend to the MPA. We currently have three years of data (2008–2010) collected as part of the ERI. Surveys are planned for the next three years.

Diadromous fish
In 2009, under the federal-provincial St. Lawrence Plan IV agreement, a Réseau d'inventaire des poissons de l'estuaire (RIPE) (E17), consisting of four experimental fishing sites in the river estuary and the upper estuary, was implemented. The cooperation of commercial eel fishers was sought because of the major fishing effort they deploy in September and October, particularly along the south shore. The only site that covered the north shore (Saint-Irénée) was abandoned. We recommend that this site continue to be monitored and that one or two other sites be added along this shore. MRNF performs various other surveys, such as monitoring the abundance of the silver eel (E20), which estimates the number of eels migrating downstream and provides an overview of the fluctuation of abundance and the condition of individuals, monitoring landings of Atlantic sturgeon in the St. Lawrence estuary (E21) and annual monitoring of salmon in Quebec rivers (E22). All these surveys adequately cover the upper estuary, but very few cover the lower estuary. Also, it is recommended that similar monitoring be established in this section of the estuary, which occupies a large part of the MPA.

Demersal fish
Every August since 1990, a multi-species fishing survey has been conducted in the northern Gulf of St. Lawrence to assess groundfish and shrimp stocks (E13). The purpose of the survey is to develop abundance and biomass indices for the various species in order to recommend levels of exploitation and total allowable catch. This survey samples the demersal fish of the estuary at depths of 30 m and more. However, coastal demersal fish and those of the upper estuary, areas highly frequented by whales, are not covered. These sampling campaigns require significant resources in terms of personnel, vessels and fishing gear.

Commercial fisheries statistics
DFO and MRNF have access to fishery statistics (active licences and landings) (E14). In the MPA, the main catches in the estuary area are snow crab and whelk (fixed gear) and in the upper estuary, eel (traps) and Atlantic sturgeon (gillnet).

Monitoring the beluga whale and harbour seal diet
Monitoring the diet of beluga whales and harbour seals (P7) provides an indirect indication of prey availability in the area. Stomach contents, the ratios of various stable isotopes such as nitrogen or carbon, fatty acid profiles, as well as profiles of the contaminant levels in animals are indirect and complementary monitoring methods. Each method has its limitations in terms of results. Their potential is maximized when used in conjunction with another method. The tissue samples required for these analyses can be obtained from the harbour seal and beluga whale carcass monitoring program and various prey surveys.

Monitoring toxic chemical contaminants in harbour seal and beluga whale prey
Monitoring the contamination of the main prey of harbour seals and beluga whales (P9) would enable us to identify the primary vectors of contamination of marine mammals residing in the St. Lawrence. It would enable us to see emerging contaminants appear in the ecosystem biota and monitor legacy contaminants, which are generally regulated but still bio-available to organisms in the environment. The choice of species and contaminants to be measured, as well as the methods of analysis, are to be targeted. The results of most chemical analyses are reliable and costs vary from one contaminant to another.

Fish habitat monitoring
In 2002, the Quebec Region, in collaboration with DFO's Area Offices and local partners, established the Capelin Observers Network (E15). This network encourages members of the general public to help identify breeding sites and dates when capelins are spawning. This monitoring has the advantage of being inexpensive, but the data are unreliable in their current state. Quality control is limited and the sampling effort is not systematic. By increasing the effort (by encouraging observers to become more involved), the monitoring could become more representative.

Seabed surveys via visual imaging (P18) are proposed for monitoring spawning sites and the structure of the sediment associated with the spawning grounds of prey species. The seabed was recently covered in a portion of the MPA, as part of the ERI. These data provide a basis for potential monitoring. Knowing the location of the sites and the spawning period will increase the reliability and ease of monitoring.

Temporal monitoring of marsh and eelgrass bed areas (P20) is proposed, because these environments are used by several prey species, many in the juvenile stage, as resting and feeding areas. However, with current knowledge, we are not able to determine whether a change in these areas would necessarily result in a quantifiable change in prey availability. Earth-based observation data (e.g.: LANDSAT, SPOT, ASTER and IKONOS) are used to conduct spatial and temporal monitoring of submerged vegetation. Orthorectified digital images, classification techniques and spatial analysis, together with field surveys of smaller areas are used to perform a quantitative analysis of water plant communities and marshes to detect their conditions and trends.

Status of the St. Lawrence estuary ecosystem

Several programs enable us to monitor the physical-chemical aspects of the ecosystem (e.g.: characteristics of the hydrological regime related to the freshwater entering the estuary, the spatial-temporal changes in oceanographic conditions, and ice coverage characteristics.) These surveys are all very reliable and easy to moderately easy to implement. These are well established surveys, such as the monitoring of the freshwater flow at the Quebec City station, the weekly monitoring of prey in the SSLMP, the thermograph network, winter water monitoring via helicopter, remote sensing of surface temperatures, the AZMP and the On-line Scientific Buoys network. An indicator of the changing characteristics of the hydrological regime linked to the open vs. closed zooplankton valve ratio, requires the development of new monitoring whose reliability and ease are lower because of more complex data processing, high costs or the need to improve the method. Monitoring the contamination of the environment in which beluga whales and harbour seals live is also proposed. This monitoring is complex due to the decline of certain toxic chemical contaminants as well as the emergence of new contaminants. In order to properly represent the environment, it is suggested that sediment contamination and a short-lived resident species be monitored. These measurements are very reliable and fairly easy except for the levels of contaminants in the water, which are more difficult and expensive to analyze.

Many programs also monitor the biological aspect of the ecosystem (phytoplankton, zooplankton, benthos, fish and marine mammals). They track the biomass, distribution or diversity of these communities. These programs include the multi-species surveys of the lower estuary, the AZMP, remote sensing of primary productivity, the Toxic Algae Monitoring Program, the Canadian Shellfish Sanitation Program, the weekly monitoring of prey in the SSLMP, RIPE, aerial beluga whale surveys, visual whale censuses, MOAs and the RQUMM. The reliability of these surveys ranges from moderate to poor and most of them are fairly easy to perform. There is currently no monitoring of benthic communities. To achieve this objective, two new surveys are proposed: i.e. the use of seabed imaging to monitor the epibenthos (P18) and sample the endobenthos (P19), which is however more expensive and involves more cumbersome logistics and tedious identification work in the laboratory.

Sources of uncertainty

Some indicators and monitoring will have to be refined and enhanced based on future scientific knowledge. For example, better knowledge of beluga whale and harbour seal habitat is required. The same applies to the locations of the spawning grounds of prey for both species.

No monitoring of marine mammals and their prey is conducted in winter in the MPA, except via the proposed passive acoustic monitoring in a few sites, which will enable us to monitor krill and whale vocalizations.

At least a quarter of the indicators require that new monitoring be established. Protocols for the proposed new monitoring must be developed and validated.

In general, the ease of conducting a survey decreases when its reliability increases, given that reliability is often dependent on sampling effort.

Some monitoring is not being performed and is important for the St. Lawrence Estuary MPA (e.g., the beluga carcass monitoring program, the demographic monitoring of harbour seals in the estuary, and the Toxic Algae Monitoring Program).

Some of the monitoring is done by various government agencies (e.g., MRNF, SSLMP). Their involvement and collaboration are necessary to ensure the efficacy of all monitoring related to the protection of marine mammals, their habitat and their prey.

CONCLUSION AND RECOMMENDATIONS

This assessment exercise, conducted by scientists specializing in various fields, provides managers with a valuable tool for developing the ecological monitoring plan for the St. Lawrence Estuary Marine Protected Area. It goes without saying that the 54 relevant indicators proposed in this assessment cannot all be monitored. However, the indicators and monitoring proposed for each threat and each potential effect, as well as the sound, simple criteria used to assess them will help managers make informed choices based on the human and financial resources available when monitoring is implemented.

Highly relevant indicators are proposed for each threat and its potential effects on marine mammals, except for the disruption of important activities of cetaceans. Some indicators and monitoring will have to be refined and enhanced based on future scientific knowledge. For example, better knowledge of beluga whale and harbour seal habitat is required. The same applies to the locations of the spawning grounds of prey for both of these species.

Existing programs monitor a number of indicators with acceptable reliability and ease. Some of these must be expanded to cover the entire the MPA. At least a quarter of the indicators require that new monitoring be set up. For example, (old and new) contaminants in sediment and water as well as in the prey of beluga whales and harbour seals are not being monitored. The threat of noise in the water is not being monitored either. Prey availability is a potential effect receiving little coverage under existing monitoring programs, especially with respect to prey such as krill, pelagic fish, coastal species of the lower estuary and demersal fish in the upper estuary. Also, implementing monitoring of the seabed and ocean circulation would enable us to assess changes in the habitats of various target species and changes in the environment in which they live. In general, the ease of conducting a survey decreases when its reliability increases, given that reliability often depends on sampling effort.

During the peer review, some recommendations were made regarding the development of the monitoring plan. They are:

- A single indicator can in and of itself be unreliable, but combining a few indicators will add strength and confidence to a single signal.

- Although annual monitoring is proposed for many indicators, in a context of reduced financial resources, it is suggested that the time between monitoring sampling periods be extended rather than decreasing the number or quality of surveys. Quality monitoring conducted every five years, for example, should have greater decision-making impact than less intense annual monitoring. The various surveys should be scheduled to be performed on alternate years.

- Monitoring the presence of whales and the availability of krill should be extended to the Gulf. For example, the fact that there are no whales in the MPA one year does not necessarily indicate a problem, but may simply mean they are elsewhere in the Gulf. This information is necessary for assessing how effective the MPA is at achieving its conservation goals.

- No monitoring of marine mammals and their prey is conducted in winter in the MPA, except via the proposed passive acoustic monitoring at a few sites, which will enable us to monitor krill and whale vocalizations.

- Some monitoring is not being performed and is important for the St. Lawrence Estuary MPA (e.g.: the beluga carcass monitoring program, the demographic monitoring of harbour seals in the estuary, and the Toxic Algae Monitoring Program).

- The various government agencies (e.g.: DFO, MRNF and the SSLMP) involved must join forces and work together to increase the efficiency of all monitoring related to the protection of marine mammals and their habitat and prey.

SOURCES OF INFORMATION

This Science Advisory Report is from the May 3-5. 2011 Review of the Draft for the St. Lawrence Estuary Marine Protected Area (MPA) Ecological Monitoring Plan. Additional publications from this process will be posted as they become available on the Fisheries and Oceans Canada Science Advisory Schedule at www.dfo-mpo.gc.ca/csas-sccs/index-eng.htm

DFO. 2000. Atelier scientifique sur les mammifères marins, leurs habitats et leurs ressources alimentaires dans le cadre de l'élaboration du projet de zone de protection marine de l'estuaire du Saint-Laurent du 3 au 7 avril 2000. 345 pp.

DFO. 2007. Proceedings of the workshop on the St. Lawrence Estuary beluga – review of carcass program. DFO Can. Sci. Advis. Sec., Report. 2007/005.

Provencher, L., R. Bailey, C. Nozères. 2012. Indicateurs et programmes de suivi pour la ZPM Estuaire du Saint-Laurent évalués par les pairs. DFO Can. Sci. Advis. Sec., Research document 2012/089.

Savaria, J.-Y., G. Cantin, L. Bossé, R. Bailey, L. Provencher and F. Proust. 2003. Proceedings from a Scientific Workshop on Marine Mammals, their Habitats and Food Resources, held in Mont-Joli (Quebec) from April 3 to 7, 2000, within the context of the St. Lawrence Estuary Marine Protected Area project. Canadian Manuscript Report of Fisheries and Aquatic Sciences 2647 : v + 127 p.

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